

# Photovoltaic Systems Research & Development Program at Sandia National Laboratories

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## ABSTRACT

The Photovoltaic Systems Research and Development Program at Sandia National Laboratories is striving to make photovoltaics a preferred electrical energy supply option by reducing the life-cycle costs, improving the reliability, and increasing and assuring the performance of fielded systems; by removing technical and market barriers to the use of the technology; and by supporting market growth for commercial U.S. photovoltaic systems. These goals are interrelated in that pursuing one of the objectives generally affects (positively or negatively) one or more of the others. Correspondingly, most activities undertaken by the program contribute to achieving more than one of the goals. This paper summarizes recent progress toward these objectives and describes areas of future program emphasis.

## Introduction

Sandia National Laboratories has been involved in photovoltaics (PV) research, development and deployment for more than 25 years. A particular emphasis of the Sandia PV program throughout its history has been the systems engineering aspect of PV technology. Systems engineering includes not only ensuring that each component is properly designed, but also that the components perform properly together over the life of the system. System engineering also includes ensuring proper installation and maintainability.

The general approach of the systems engineering program is to partner with industry and other organizations to achieve the goals of the U.S. Department of Energy's 5-Year Plans and, more recently, the PV Industry Roadmap [1,2]. The Southeast and Southwest Region Experiment Stations (RES's) at the Florida Solar Energy Center (FSEC) and New Mexico State University's Southwest Technology Development Institute (NMSU/SWTDI) are integral parts of the Sandia program.

### 1. Reducing Life-Cycle Costs

Cost has always been a key issue in the photovoltaics industry. Although costs of PV modules and systems have fallen dramatically over the lifetime of the industry, and there are many applications where PV is the most economical energy-supply choice, the cost per kilowatt-hour of electricity generated by PV is still significantly higher than traditional alternatives in many market sectors. This has relegated PV to providing only a tiny fraction of the electricity consumed in the U.S.

It is important to look at life-cycle costs, not just installed costs [3]. Recent work looking at the actual life-cycle costs of installed PV systems has shown that a significant portion of the life-cycle costs is due to unanticipated transaction costs, such as insurance, and unplanned maintenance [4]. This substantially increases the actual cost per kilowatt-hour of the electricity generated.

Uncertainty surrounding the actual life-cycle costs of PV-generated electricity has been given as a major reason for

reluctance on the part of electric cooperatives in making greater use of PV technology. Sandia and its partners are currently populating a database to track and analyze fielded systems in selected applications to better understand true life-cycle costs. Next steps will be to prioritize opportunities for cost reduction and pursue them. [5]

### 2. Improving Reliability

A major focus of Sandia's PV Systems R&D program is improving the reliability of fielded systems. There is considerable anecdotal information indicating that many PV systems are not performing as expected in the field. Unless these reliability issues are addressed, the markets for PV technology will be hindered significantly. However, there is currently insufficient information available to resolve this issue in a scientific and credible way. At the request of the Department of Energy, Sandia recently prepared a plan to use a systematic and scientific approach to define and achieve PV system lifetimes of 25 years [6]. Key elements of this plan include the following:

- Developing a better understanding of the reliability of fielded systems through further development of reliability databases.
- Conducting detailed investigations of field-aged systems and components to quantify performance degradation, identify degradation mechanisms and root causes for failures, and facilitate manufacturing improvements.
- Modeling system performance and reliability to identify fault-tolerant designs, performance sensitivity to component failures, and cost of different component replacement strategies.
- Developing solutions to priority problems, working in partnership with appropriate industry members or other organizations. In some cases, the issues may be technical (such as inverters) and in other cases they may be infrastructural or institutional (such as lack of capacity within a user organization to properly manage and maintain a PV system).

### 3. Increasing and Assuring Performance

Increasing the performance of PV systems and components contributes to reduced life-cycle costs. Sandia's program addresses performance issues through two types of activities: (1) by advancing PV technology through research and development on components, systems, and processes to increase the energy produced per unit \$, material, area, etc., and (2) by contributing to the development of "best practices" to assure performance in the field.

The first activity involves characterizing (measuring, modeling) system performance, identifying performance-limiting mechanisms, and then developing alternatives to overcome limitations. Recent R&D includes comprehensive performance and safety evaluation of small stand-alone systems for rural applications, round-robin module calibrations in support of

laboratory accreditation at FSEC and Arizona State University, and diagnostic evaluation of field durability issues identified in commercial modules.

The second activity includes the development of standards to set common minimum limits for performance; development of codes to ensure safety, and which are necessary for acceptance of technology; development of certification procedures to improve the quality of installations, and development of accreditation programs to assure the quality of (the facility conducting) testing. In FY2001, the program completed work to change the 2002 edition of the National Electrical Code and contributed to IEEE, IEC, and Underwriters Laboratories' PV standards. Accreditation and certification programs progressed with the establishment of FSEC as an accredited and certified training and testing facility and the establishment of a hardware certification program at Sandia.

#### 4. Removing Barriers

Removing barriers to the development, manufacture, and use of photovoltaic technologies has long been a focus of Sandia's PV program. Through the PV Design Assistance Center (aka PV Systems Assistance Center), Sandia and the RES's have provided technical assistance, helped build capacity and infrastructure, and disseminated vast amounts of information about PV technology to hundreds of organizations [7].

Technical assistance includes hardware evaluation and testing, help with project development and system specifications, and troubleshooting for both industry and users of the technology. Recent technical assistance is described in Reference 7.

Capacity building and infrastructure development includes targeted training of and collaborative activities with industry, decision makers, technology users, designers & architects, installers, and inspectors. Recent training activities are described in Reference 7. As an example of a collaborative activity to build capacity, Sandia is working with students of colleges and universities in New Mexico to develop a solar car team for the 2003 American Solar Challenge. Native American students are being recruited to join the team, which will help build the capacity to make use of PV technology within the Native American community.

Sandia maintains a repository of information accessible through a web site, and actively disseminates papers and publications to target audiences. Sandia hosted a Photovoltaic Systems Symposium in Albuquerque, NM in July 2001 that was attended by more than 200 industry, government, utility and institutional partners.

#### 5. Supporting Market Growth

While marketing itself is considered the domain of the private sector, there are many instances where targeted R&D, technical assistance, and/or collaborations by the national laboratories can provide unique assistance to contribute to the growth of markets for the U.S. photovoltaic industry. Sandia's work in this area falls into three categories:

New Applications: Working with industry, Sandia and its partners are developing new applications for PV technology. This is essentially R&D with a view toward untapped markets. Seven sectors have been identified as promising near term opportunities for substantial market growth if the necessary systems engineering R&D was undertaken: transportation,

remote instrumentation and monitoring, commercial and industrial lighting and signage, water purification, refrigeration, building envelope temperature control, and defense [8].

Technology Commercialization: Sandia and the RES's provide key assistance to the industry in commercializing their systems technology. This work includes laboratory and field testing of components and systems, troubleshooting and analysis, feedback and redesign. For example, Sandia recently completed evaluations of two systems designed to provide power for homes in the Navajo Nation. In addition to contributing to the commercialization of PV technology, this laboratory and field work provides Sandia and the DOE PV program with up-to-date experience with and understanding of PV systems that is critical to maintaining a state-of-the-art PV system engineering capability.

Technology Deployment: Another way in which the systems engineering program contributes to the growth of markets is by implementing deployment programs in close partnership with organizations that can make wide use of PV systems. The program provides technical assistance in the implementation of pilot projects to build capacity within these organizations. The program helps the organizations mainstream the use and procurement of PV technology, and sets the stage for large-scale project replication. For example, working with the U.S. Department of Agriculture's Rural Utility Service (RUS) to mainstream the use of PV in its operations with rural utilities opens up a vast market for PV. Experience gained through these deployment projects provides valuable lessons learned about fielding PV technology that are fed back into the other systems engineering activities. In addition to the RUS, current partnerships include the U.S. Department of Defense, the U.S. Agency for International Development, the Florida Solar Buildings Program, the U.S. Bureau of Reclamation, Mexico's Agriculture Secretariat, Salt River Project, and the Navajo Tribal Utility Authority. Partnerships under development include a number of organizations in California, such as the California Energy Commission and the Sacramento Municipal Utility District.

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